Series 1938, No. 1 Issued March 1941

Soil Survey

Yuma Desert Area Arizona

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UNITED STATES DEPARTMENT OF AGRICULTURE
BUREAU OF PLANT INDUSTRY
In cooperation with the
University of Arizona Agricultural Experiment Station

For sale by the SUPERINTENDENT OF DOCUMENTS, WASHINGTON, D. C. Price 40 cents

This publication is a contribution from

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SOIL SURVEY OF THE YUMA DESERT AREA, ARIZONA

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Area inspected by MACY H. LAPHAM, Inspector, District 5

United States Department of Agriculture in Cooperation with the University of Arizona Agricultural Experiment Station

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AREA SURVEYED

LOCATION AND EXTENT

The Yuma Desert area is in the southwestern part of Yuma County near the extreme southwestern corner of Arizona (fig. 1). The northwestern part of the area is immediately south of United States Highway No. 80, and about 10 miles southeast of Yuma by air line. From that point the area extends eastward to the Gila Mountains and southward to the international boundary between Arizona and the State of Sonora, Mexico. Boundaries have been drawn to include 272 square miles, or 174,080 acres, of dry desert lands for which it is proposed that irrigation water will be supplied. The western boundary of this area is formed by the eastern boundary of the area covered by the soil survey of the Yuma-Wellton area, Arizona-California.[2]

[1] The field work for this survey was done while the Division was a part of the Bureau of Chemistry and Soils.

[2] YOUNGS, F. O., HARPER, W. G., THORP, JAMES, and ISAACSON, M. R. SOIL SURVEY OF THE YUMA-WELLTON AREA, ARIZONA-CALIFORNIA. U. S. Bur. Chem. and Soils ser. 1929, No. 20, 37 pp., illus. [1933.]

PHYSIOGRAPHY, RELIEF, AND DRAINAGE

The elevation of the lowest (northwestern) part of the area is about 250 feet above sea level and that of the eastern part, exclusive of rough mountainous areas, is about 600 feet above sea level. The mountainous areas include the lower slopes of the Gila Mountains, which are rough, rugged, stony, and practically barren of vegetation. Sloping westward from the mountains are alluvial fans built from rock debris that has washed from the mountains. The higher and steeper fans are stony and somewhat dissected, but at a distance of a few miles from the mountains they become smooth and gently sloping. In the northern half of the area the fans merge with the

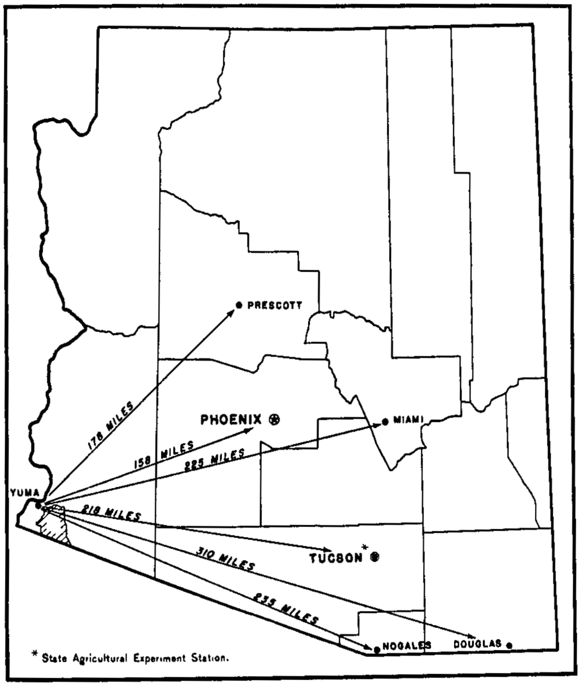

FIGURE 1.—Sketch map showing location of the Yuma Desert area, Arizona.

comparatively high old alluvial terraces of the Colorado River. In some places these old terraces are smooth and gently sloping, whereas in other places erosion has left them rolling or roughly dissected. In the south-central part of the area smooth gently sloping alluvial fans are separated from the Colorado River terraces by an area of dunes or hummocky sands, which ranges in width from 1 to 4 miles and extends northward about 14 miles from the international boundary.

Near the mountains the stream channels are 10 feet or more deep and as much as 200 feet wide, but most of them extend only a few miles beyond the mountains, where they spread out and the water they carry sinks into the porous sandy or gravelly material. Fortuna Wash, the largest channel in the area, is dry most of the time,

but after periods of unusually heavy rainfall water runs through it to the Gila River.

VEGETATION

The native vegetation is characteristic of extensive areas in the southwestern desert region, where a rather sparse stand of brush is prevalent. Creosotebush (*Covillea tridentata*), known locally as greasewood, is widespread in this area. Bur-sage is very common and rather widespread. Galleta grass grows abundantly on the hummocky sandy soils. In the areas of sand dunes is a sparse stand of jointfir, a bushy plant locally caled Mormon tea. Adjacent to stream channels where moisture is most abundant, paloverde, ironwood, and mesquite trees are common. Giant cactus, ocotillo, cholla, and a few other less common cacti grow abundantly on the higher fan slopes near the mountains.

POPULATION, TRANSPORTATION, AND INDUSTRIES

All the area is desert land for which irrigation has not been developed. Only six houses are in the area; five of these are at Fortuna mine and are used by miners; and the one on United States Highway No. 80 is used in connection with a gasoline service station. Yuma, which had a population of 4,832 in 1930 and is the county seat of Yuma County, may be reached from the northern part of the area by paved highway at a distance of about 14 miles, whereas the southeastern or most distant part of the area is about 35 miles from Yuma. United States Highway No. 80 forms the northern boundary of the area, and an ungraded road leads south from the highway past Fortuna mine into Sonora, Mexico, several miles to the southeast. Only a few other recently cleared section lines are used as secondary or surveyor's roads. The main rail line of the Southern Pacific Co. between Yuma, Phoenix, and more distant points passes within a mile of the northern margin of the area. No industries, other than some mining near Fortuna mine, are in operation.

CLIMATE

The Yuma Desert area lies at a low altitude in the arid Southwest. It is cut off from the moderating influence of the Pacific Ocean and its moisture-laden winds by the Coast Range of mountains in California; and, as a result, it has the continental or inland climate characteristic of much of Arizona, southern Nevada, and parts of California. The climate is characterized by little rainfall, a dry atmosphere, rapid evaporation of moisture, and an unusually high percentage of sunshine; in fact, a day without some sunshine is extremely rare. The mean annual temperature is high, the summers are long and hot, and the winters are short and mild, with occasional frost. The daily range of temperature is greater than in most parts of the United States. Strong winds are common and, especially during spring, duststorms and sandstorms often occur. During these storms the shifting sand may damage crops by cutting the tender plant tissue, by burying the shoots, or by blowing the soil away from small plants. The prevailing winds are from the northwest.

The average length of the frost-free season at the Yuma Citrus Station, which is located on the mesa a few miles south of Yuma, is 325 days. The average date of the first killing frost is December 13 and that of the latest is January 22. Frost has been recorded as late as February 27 and as early as November 13, and some winters are frost-free. The presence of thrifty ironwood trees generally indicates an area comparatively free from frost, so it is very probable that much of the eastern part of this area has even less frost than has been recorded at the Yuma Citrus Station.

The average annual precipitation is only 3.92 inches. This is not sufficient to be of much practical value to growing crops. Most of the rain falls during winter.

Table 1 gives the normal monthly, seasonal, and annual temperature and precipitation at the Yuma Citrus Station.

TABLE 1.—*Normal monthly, seasonal, and annual temperature and precipitation at Yuma Citrus Station, Yuma County, Ariz.*

[Elevation, 191 feet]

Month	Temperature			Precipitation		
	Mean	Absolute maximum	Absolute minimum	Mean	Total amount for the driest year (1924)	Total amount for the wettest year (1921)
	°F.	°F.	°F.	Inches	Inches	Inches
December	54.8	82	28	0.68	0.29	0.89
January	53.0	86	24	.27	.00	.88
February	59.0	91	29	.26	.00	.00
Winter	55.6	91	24	1.21	.29	1.77
March	63.9	96	33	.18	.12	.00
April	69.5	105	34	.20	.10	.00
May	77.1	113	42	.02	.00	.06
Spring	70.2	113	33	.40	.22	.06
June	85.0	117	50	.00	.00	.00
July	91.1	116	60	.25	.00	.42
August	91.4	116	63	.68	.00	1.58
Summer	89.2	117	50	.93	.00	2.00
September	84.9	112	52	.70	.00	3.48
October	73.5	106	40	.51	.00	.00
November	62.2	98	29	.17	.00	.00
Fall	73.5	112	29	1.38	.00	3.48
Year	72.1	117	24	3.92	.51	7.31

The University of Arizona Agricultural Experiment Station has made a study of the effect of the climate of southern Arizona on various crop plants.[3] It is stated that aridity or low relative humidity of the atmosphere is not generally favorable to plant growth. Not many plants thrive as well in a dry atmosphere as in a more humid one, and only a very few grow better under such a condition. The intense sunlight is detrimental to some plants, causing sunburn.

[3] McCLATCHIE, ALFRED J., and COIT, J. ELIOT. RELATION OF WEATHER TO CROPS AND VARIETIES ADAPTED TO ARIZONA CONDITIONS. Ariz. Agr. Expt. Sta. Bul. 78, pp. [45]–118, illus. 1916.

Some seeds will not germinate in the hottest weather, some plants are brought to maturity, and others are killed outright. The frosts kill many tender plants; otherwise tropical plants might thrive. In effect the growing season for most crops is divided into two parts, spring and autumn.

Alfalfa and cotton are the most important staple crop plants considered well adapted to this climate. Even alfalfa has a period of retarded growth in the hottest part of summer as well as in midwinter, and cotton must be carefully and frequently irrigated in the hottest weather if the fruiting stage is reached. The grain sorghums—milo, kafir, hegari, feterita. and others—are very well adapted to the hot dry summer, but such temperate-climate grasses as Kentucky bluegrass, bromegrass, orchard grass, and Italian ryegrass, locally called Australian ryegrass, are killed by the heat. The date palm is especially well adapted to this climate; the European or viniferous varieties of grapes, and olives, figs, and pomegranates also do well. Of the citrus fruits, grapefruit and oranges are adapted to a few comparatively frost-free belts. They are occasionally damaged by winter frosts and freezes, and in summer the trunks of the trees may sunburn badly if not shaded. Some crops do very well in fall, winter, and spring but do not succeed in the summer. Among these are lettuce, peas, spinach, carrots, cabbage, and many other vegetables. Tomatoes produce a crop in the spring, lie dormant through the summer, and produce a second crop in the autumn. Sweetpotatoes grow well throughout the summer and produce good yields. Potatoes are very difficult to grow, as growth is checked by early hot dry weather, and yields are normally light. The small grains are sown from November to February and make good growth during winter and early spring. They cannot endure the hot dry weather of late spring and summer, and regardless of the time they are sown, they come to maturity in April or May. Yields are generally lower than in cooler climates.[4]

AGRICULTURE

Although no farming is done in the area at present (1938), very similar soils have been cultivated near Yuma and in other parts of Arizona. The soil at the Yuma Mesa Experimental Farm of the University of Arizona is similar to soils of the Superstition series in this area. Soils farmed in the Salt River Valley and in other valleys of southern Arizona are somewhat similar to those of the Anthony, Mohave, and Cajon series mapped in this area. Although some sections (640 acres each) in this area have been deeded under the homestead laws, most of the land has been withdrawn from further entry and is held for development under reclamation acts. When water is provided, the land may be made available to prospective settlers at a price presumed to pay for the cost of developing the water supply. Payments are usually distributed over a long period.

SOIL-SURVEY METHODS AND DEFINITIONS

Soil surveying consists of the examination, classification, and mapping of soils in the field.

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[4] See footnote 2, p. 1.

The soils are examined systematically in many locations. Test pits are dug, borings are made, and exposures, such as those in road and railroad cuts, are studied. Each excavation exposes a series of distinct soil layers, or horizons, called, collectively, the soil profile. Each horizon of the soil, as well as the parent material beneath the soil, is studied in detail; and the color, structure, porosity, consistence, texture, and content of organic matter, roots, gravel, and stone are noted. The reaction of the soil [5] and its content of lime and salts are determined by simple tests.[6] Drainage, both internal and external, and other external features, such as relief, or lay of the land, are taken into consideration, and the interrelation of soils and vegetation is studied.

The soils are classified according to their characteristics, both internal and external, special emphasis being given to those features influencing the adaptation of the land for the growing of crop plants, grasses, and trees. On the basis of these characteristics, soils are grouped into mapping units. The three principal ones are (1) series, (2) type, and (3) phase. Areas of land that have no true soil, such as coastal beach or bare rocky mountainsides, are called (4) miscellaneous land types.

The most important group is the series, which includes soils having the same genetic horizons, similar in their important characteristics and arrangement in the soil profile, and developed from a particular type of parent material. Thus, the series includes soils having essentially the same color, structure, and other important internal characteristics and the same natural drainage conditions and range in relief. The texture of the upper part of the soil, including that commonly plowed, may vary within a series. The soil series are given names of places or geographic features near which they were first found. Thus, Mohave and Whitlock are names of important soil series in this county.

Within a soil series are one or more soil types, defined according to the texture of the upper part of the soil. Thus, the class name of the soil texture, such as sand, loamy sand, sandy loam, loam, silt loam, clay loam, silty clay loam, and clay, is added to the series name to give the complete name of the soil type. For example, Whitlock sand and Whitlock loamy sand are soil types within the Whitlock series. Except for the texture of the surface soil, these soil types have approximately the same internal and external characteristics. The soil type is the principal unit of mapping, and because of its specific character it is usually the soil unit to which agronomic data are definitely related.

A phase of a soil type is a variation within the type, which differs from the type in some minor soil characteristic that may have practical significance. Differences in relief, stoniness, and the degree of accelerated erosion are frequently shown as phases. For example, within the normal range of relief for a soil type there may be areas

[5] The reaction of the soil is its degree of acidity or alkalinity expressed mathematically as the pH value. A pH value of 7 indicates precise neutrality; higher values indicate alkalinity, and lower values indicate acidity.

[6] The total content of readily soluble salts is determined by the use of the electrolytic bridge. Phenolphthalein solution is used to detect a strong alkaline reaction.

that are adapted to the use of machinery and the growth of cultivated crops and others that are not. Even though there may be no important differences in the soil itself or in its capability for the growth of native vegetation throughout the range in relief, there may be important differences in respect to the growth of cultivated crops. In such an instance the more sloping parts of the soil type may be segregated on the map as a sloping or a hilly phase. Similarly, soils having differences in stoniness may be mapped as phases, even though these differences are not reflected in the character of the soil or in the growth of native plants.

The soil surveyor makes a map of the county or area, showing the location of each of the soil types, phases, and miscellaneous land types, in relation to roads, houses, streams, lakes, section and township lines, and other local cultural and natural features of the landscape.

SOILS AND CROPS

Southwestern Arizona is a desert country where production of crops depends on irrigation. Rainfall is so light that the soluble materials in the soils have not been leached to a great depth nor have the soils undergone much loss of mineral constituents contained in the original geological deposits. They contain high percentages of lime (calcium carbonate), potash, and phosphorus. Owing to the high lime content of some of the soils, however, available phosphorus is deficient in places, even though the total phosphorus content may be high. On most of such soils, applications of phosphate fertilizers are beneficial. The very small supply of nitrogen makes essential manuring or the plowing under of alfalfa and cover crops such as *Sesbania* and Hubam sweetclover.

In this survey 5 series of soils including 14 soil types and 7 soil phases besides 5 miscellaneous land types have been mapped. The characteristics of the different soil types are related to the mineralogical composition and degree of fineness of the parent materials, to the length of time these have been in place, and to position, so far as position has affected the quantity of moisture received during development of the soil.

Sediments from which the soils of the Cajon, Anthony, Mohave, and part of those of the Whitlock series have developed have been derived from rock material that has been washed from the Gila Mountains. These materials are largely from granite and similar igneous rocks. Some of the Whitlock and the Superstition soils are developed from old Colorado River terrace material and from wind-laid sandy material. The wind-laid sands have been transported from the sandy alluvial fans and terraces and possibly from old beaches that were formed when the Imperial and Coachella Valleys were inundated to a great extent.

In the following pages the soils of the Yuma Desert area are described in detail, and their agricultural possibilities and treatment are discussed; their location and distribution are shown on the accompanying soil map; and their acreage and proportionate extent are given in table 2.

TABLE 2.—*Acreage and proportionate extent of the soils mapped in the Yuma Desert area, Arizona*

Soil type	Acres	Percent	Soil type	Acres	Percent
Mohave loamy sand	12,160	7.0	Anthony fine sand	4,480	2.6
Mohave loamy coarse sand	896	.5	Anthony loamy sand	7,040	4.0
Mohave gravelly sandy loam	192	.1	Cajon loamy sand	3,072	1.8
Whitlock loamy sand	8,576	4.9	Cajon loamy coarse sand	4,288	2.5
Whitlock loamy sand, shallow phase (over Mohave soil material)	3,776	2.2	Cajon sand	512	.3
Whitlock loamy sand, deep phase	9,472	5.4	Cajon sand, hummocky phase	2,432	1.4
Whitlock loamy sand, eroded phase	14,464	8.3	Cajon fine gravelly sand	896	.5
Whitlock sand	12,288	7.0	Dune sand	5,376	3.1
Whitlock sand, dune phase	2,432	1.4	Dune sand, low-dune phase	13,824	7.9
Whitlock gravelly sandy loam	16,768	9.6	Rough broken and stony land (Whitlock soil material)	11,456	6.6
Whitlock gravelly sandy loam, dune phase	2,432	1.4	Rough stony land	7,360	4.2
Superstition loamy sand	4,096	2.4	Riverwash	2,560	1.5
Superstition sand	3,776	2.2	Total	174,080	
Superstition sand, hummocky phase	19,456	11.2			

MOHAVE SERIES

The Mohave soils lie mainly on alluvial fans in the southeastern part of the area. The mineral material of these fans has washed from the Gila Mountains and includes material derived from granite, granitic schist, gneiss, and to less extent from other igneous and altered rocks of mixed mineralogical character. In some respects soils of the Mohave series have a stronger profile development, that is, greater differentiation of surface and subsoil layers, than do other soils of the area. This may be due partly to a larger amount of moisture that is received in the form of run-off from the mountains and to its effect on hydrolysis of feldspathic minerals in the granitic materials. The differences between the Mohave soils, on the one hand, and the Anthony and Cajon soils on the other, probably are due largely to a longer period of soil formation, that is, a longer period since the soil materials were deposited. Soils of the Mohave series have light reddish-brown noncalcareous friable surface soils underlain by more compact mildly calcareous reddish-brown subsurface soils and highly mottled brownish-red and comparatively highly colloidal limy subsoils, which become hard or tough and somewhat cemented when dry.

Mohave loamy sand.—The uppermost 7 inches of Mohave loamy sand is light pinkish-brown firm but friable noncalcareous slightly micaceous gritty loamy sand. The sand and gritty particles are angular in shape, high in content of quartz, and mainly of granitic origin. Beneath this layer is reddish-brown or brownish-red somewhat compact noncalcareous sandy loam. Between depths of about 9 and 20 inches is mildly or moderately calcareous rich reddish-brown heavy sandy loam. The upper part of this layer contains a few tiny veins of gray lime, and below these are flecks and spots of gray lime. This material is underlain by reddish-brown sandy loam that has a high colloidal content, gray or white spots, and some irregular-shaped but somewhat rounded lime nodules. When dry this material is too hard or tough to be penetrated easily with a shovel and difficult to dig even with a bar, but when moist it may be dug easily with a shovel. This layer extends to a depth of about

44 inches and is underlain by material of very similar character that contains slightly coarser sand and gravel fragments. Between depths of 74 and 84 or more inches is light grayish-brown comparatively loose and porous highly calcareous loamy fine gravelly and coarse sandy material. Practically all of the sand and fine gravel appears to be of granitic origin, very angular, and but very slightly disintegrated or chemically altered since deposition.

The largest body occurs about 3 miles southwest of Fortuna mine, and several smaller areas are farther south and east. Several very small bodies are near the northwestern margin of the area, and one body is in sec. 13, T. 11 S., R. 23 W. There is considerable variation in some of these areas. Two small bodies that contain considerable gravel both on and in the surface soil are indicated on the map by gravel symbols. In some places in sec. 36, T. 10 S., R. 21 W., gravelly material occurs in the subsoil. On the surface of much of the large area and especially near its northern limits is considerable recently deposited angular granitic loamy coarse sand or fine gravel. This is also true of parts of other bodies in the southeastern part of the area. This recently deposited material has been washed from the slopes of the Gila Mountains, and as the streams separate and spread out the material has been dropped in narrow or small fan-shaped depressions. The seven areas in secs. 5 and 7, T. 10 S., R. 22 W., and the area in sec. 13, T. 11 S., R. 23 W., differ somewhat in that the surface soil is slightly more compact, slightly redder, and generally is calcareous with a few lime nodules at or very near the surface. This condition may be due to loss of the original surface soil and exposure of the subsoil through erosion. The parent material and gravel of these latter bodies also differ from those of other areas. Here, the parent material consists of old Colorado River terrace deposits including much rounded gravel of mixed mineralogical composition.

A fairly large area of Mohave loamy sand is mapped. The surface is smooth and very gently sloping. A few intermittent drainage courses that are only a few inches deep cut through the slopes in places but spread out and disappear in the flatter areas. The texture and structure of the surface soil, subsoil, and substrata are such that poor drainage probably will not develop after irrigation. The native cover includes creosotebush; ocotillo; bur-sage; cholla, giant, and other kinds of cacti; and a number of annual plants, weeds, and grasses that grow rapidly to maturity following spring rains.

With development of irrigation this soil should be comparatively desirable and productive, and the irrigation requirements should be less than on other soils of the area surveyed. On similar but somewhat finer textured soils in other parts of southern Arizona, about 3 acre-feet of water is used for alfalfa and usually a smaller quantity is required for other crops. Probably somewhat more water would be needed on this soil.

Mohave loamy coarse sand.—To a depth ranging from a few inches to as much as 20 inches in some places, Mohave loamy coarse sand is light-brown or rich-brown noncalcareous loose loamy coarse sand—apparently a comparatively recent overwash of angular granitic material. Beneath it is a thin layer of rich-brown or reddish-brown

more compact gritty coarse sandy loam, which when dry is easily dug with a shovel. At a depth ranging from 10 to 24 inches is material of very similar character and structure but which contains a small quantity of free lime. This material grades rapidly into more compact, denser, and slightly heavier textured reddish-brown gritty loam containing a number of gray flecks and nodules of lime. It is somewhat cemented and difficult to penetrate with a pointed bar when dry, but when moist it may be dug easily with a shovel. It gives way at an average depth of about 5 feet to light-brown more friable or loose highly calcareous coarse sand and fine gravel or slightly loamy material.

There are only two small bodies of this soil. They are about 5 and 8 miles, respectively, south of Fortuna mine. The surface is smooth and gently sloping. The soil has developed on alluvial-fan materials washed from the Gila Mountains and deposited on an outwash plain about 4 miles from the mountains. The parent rocks are mainly of granitic origin, with a small admixture of various other rocks. Following a heavy rain the run-off flows on to lower land either through shallow surface washes or as sheet wash. Owing to favorable internal characteristics, this soil probably would have good drainage under irrigation and would prove to be one of the more desirable soils of the area surveyed. It should be fairly well adapted to the production of most of the crops suited to southern Arizona. The water requirement should be low, compared with that of many other soils of the area.

Mohave gravelly sandy loam.—The surface of Mohave gravelly sandy loam is covered with a desert pavement consisting of a layer of dark-brown or black burnished gravelstones that, owing to weathering, appear to have been varnished on the top sides or on the surfaces exposed to the sun and rain. The gravel and the parent material are mainly granitic. Beneath the surface gravel, and continuing to an average depth of about 10 inches, is pale reddish-brown or reddish-brown firm but friable moderately calcareous gravelly sandy loam. This is underlain by grayish- or pinkish-brown slightly cemented highly calcareous stony and gravelly loamy material. The gray color is due principally to accumulations of lime. At an average depth of about 36 inches this material is underlain by more highly cemented pinkish-gray gravelly loam that has a high content of lime and a slightly higher content of colloids than the horizon immediately above. This more firmly cemented horizon continues to a depth of about 54 inches, where it rests on light reddish-brown rather loose porous gravelly and sandy material. This material is slightly loamy and mildly calcareous, but it contains spots with a high lime content.

Two bodies of this soil are near the northeastern margin of the area, and one small body is near the southwestern corner of sec. 36, T. 10 S., R. 21 W. The total area of the three bodies is very small.

The surface is smooth and gently sloping, and external and internal drainage are adequate or excessive. The high gravel and stone content, the open leachy character of the subsoil, and the low water-holding capacity of the soil, however, present conditions highly unfavorable to its reclamation and use.

WHITLOCK SERIES

In places the Whitlock soils have developed from materials very similar to those of the Mohave soils, and in other places the parent material consists of old terrace sediments of the Colorado River or a combination of alluvial-fan, river-terrace, and wind-laid materials. The Whitlock soils have light reddish-brown very mildly calcareous or noncalcareous friable surface soils, moderately calcareous subsurface soils of similar or slightly lighter reddish brown color, and rather highly lime-impregnated pinkish-brown or reddish-brown subsoils. The comparatively high content of colloids and the more pronounced red color characteristic of the Mohave soils are wanting in the Whitlock soils. The deeper horizon of lime accumulation is generally more pronounced than in the Mohave soils. The subsoil of both the Mohave and the Whitlock soils is somewhat cemented. A pointed iron bar generally is necessary for digging into the dry material, but the soils of either series may be dug with a shovel when the material is thoroughly moistened.

Whitlock loamy sand.—Although a few bodies of Whitlock loamy sand have developed from alluvial materials washed from the Gila Mountains, most of this soil has developed mainly from the Colorado River terrace deposits. The surface is covered with a few or many small well-rounded dark-brown or black gravelstones, forming what is known as a desert pavement. The particles of gravel have a dark burnished appearance on their upper or exposed surfaces, though the under sides or fresh fractures have, in places, a light or variable color, depending on their origin and mineral character. The gravel has accumulated on the surface after the finer textured material has been removed by wind or water.

The 10-inch surface layer consists of loose structureless very mildly calcareous loamy sand that is pale reddish brown when dry and slightly more pronounced reddish brown when moist. It is underlain to a depth of about 18 inches by light reddish-brown mildly calcareous slightly firmer sandy loam. When an excavation is made in this layer, the material is sufficiently firm so that it does not cave, but it is easily crushed in the hand. This layer grades into one of more pronounced lime accumulation. This material is slightly cemented and is slightly heavier in texture and slightly redder than the overlying material. It is highly calcareous and contains many small irregular-shaped lime nodules. Between depths of about 26 inches and 3 feet or more, the material is grayish- or pinkish-brown very highly calcareous loamy sand or gravelly loam. This layer is cemented so much, mainly by lime, that it is difficult to dig with a shovel, but it is easily broken into irregular-shaped fragments by using a sharp blade or a pointed iron bar. Beneath it is light reddish-brown very friable highly calcareous gravelly loam, loamy sand, or sand that contains much coarse sand and a few gray or white nodules or fragments of lime. This loose porous material generally continues to a depth of several feet.

The soil occurs in many small bodies in the western and northern parts of the area. The surface, although smooth, is slightly hummocky or rolling to such an extent that some expense would be required for leveling or for the construction of contour canals. In

most bodies in the southwestern part of the area, porous gravelly material is near the surface; therefore, leveling is not advised, but distribution of water in contour ditches would be required.

Both external and internal drainage are adequate or excessive under natural conditions, and it is probable that poor drainage would not follow the development of irrigation. Careful irrigation would be essential in all locations where the surface soil is gravelly or very porous. The water requirement in such places would be very high, and crop yields would not be high unless cover crops were grown and returned to the soil.

This soil adjoins a small body of Superstition sandy loam, heavy-textured subsoil phase, of the Yuma-Wellton area, which represents a transition into the Whitlock soils.

Whitlock loamy sand, shallow phase (over Mohave soil material).—The upper layers of Whitlock loamy sand, shallow phase (over Mohave soil material), are very similar to those of the typical soil. The parent material, however, has been derived entirely from alluvial materials washed from the Gila Mountains. Dark smooth burnished angular gravel, mainly of granitic rocks, covers the surface of most areas, forming a desert pavement. Beneath this superficial gravelly layer and extending to an average depth of about 10 inches is light reddish-brown loose structureless very mildly calcareous loamy sand. Below this and extending to a depth of about 18 inches is mildly calcareous somewhat firm loamy sand. This material grades into slightly heavier textured loamy sand which is more highly calcareous, contains lime nodules, and is weakly cemented. Between depths of about 34 and 50 inches is light reddish-brown loam or fine sandy loam with many gray or white lime splotches or nodules. When dry this horizon is partly cemented and is difficult to dig with a shovel but may be broken easily with a pointed bar. When moist it is easily removed with a shovel. This material is underlain rather abruptly by light reddish-brown gritty or gravelly heavy loam or fine sandy loam that contains many gray flecks or nodules of lime and a much higher proportion of colloids than the layer immediately above. It is also more firmly cemented or difficult to penetrate with a bar than that layer, but when moist it may easily be removed with a shovel. It has much better water-holding capacity than the lower subsoil material of the typical Whitlock soils. This heavier textured light reddish-brown material is probably not a natural development of Whitlock loamy sand but represents the lower horizons of a soil similar to a type of the Mohave series, from which the original surface material has been eroded. Subsequent to such erosion it was buried by more recent deposits of Whitlock material. Depth to the heavier textured material varies from place to place, in many places being more than 6 feet. In the four bodies in T. 9 S., R. 21 W., this heavier light reddish-brown material is not everywhere present, but the highly cemented layer of the subsoil is heavier than in the typical soil. Such areas have been included with this phase of Whitlock loamy sand.

This soil occurs in several bodies in the central, north-central, and extreme southeastern parts of the area. Conditions are such that poor drainage probably would not develop following the application of irrigation water. Although this soil might require slightly more

water and might not be quite so desirable as the Anthony and most of the Mohave soils, it is one of the more promising soils of the area.

Whitlock loamy sand, deep phase.—The topmost 5 inches of Whitlock loamy sand, deep phase, consists of somewhat firm but very friable mildly calcareous loamy sand, pale reddish brown when dry and slightly richer reddish brown when moist. The mineral components are mainly angular granitic sand or fine sand. Below this material and continuing to a depth of about 26 inches—in some places 36 inches—the material is slightly coarser and becomes slightly more calcareous with depth, generally being moderately calcareous at a depth of 30 inches below the surface. It is underlain by light reddish-brown highly calcareous loamy sand and coarse sand, and many irregular-shaped, but somewhat rounded, nodules of lime are scattered through the layer. The lime, together with other mineral constituents, has cemented the soil to a slight extent, but it may be easily dug with a shovel. Beginning at an average depth of about 3 feet, however, is a layer of grayish- or pinkish-brown loamy sand and coarse sand containing a higher percentage of lime and more firmly cemented than the material immediately above. This material is very difficult to dig into with a shovel, but by the use of a pointed iron bar it is easily broken. The cemented layer ranges from 8 to 15 inches in thickness. In some places it is underlain by light-brown moderately calcareous loose granitic sand, coarse sand, and fine gravel, but in other places it is underlain by material similar to that of the subsoil of Mohave loamy sand. The heavier textured material, which resembles the subsoil of the Mohave soils, lies within 8 feet of the surface in most places and probably everywhere within 12 feet of the surface.

Whitlock loamy sand, deep phase, occurs in the southeastern part of the area, where several bodies cover a combined area of about 15 square miles. The surface in general is smooth and gently sloping. The soil is developed mainly on alluvial-fan material washed from the Gila Mountains. In some places, however, the surface soil contains much fine sand, which has been blown onto the soil from areas of dunes and other wind-shifted soil material situated just west of areas of this soil. The predominant vegetation consists mainly of a sparse stand of creosotebush that has attained a height ranging from 3 to 8 feet. Bur-sage grows here and there, but the more tender grasses and annual plants are kept cut off by the blowing sand. There are some small hummocks of sand, but they are not large enough to cause appreciable expense when the land is prepared for irrigation. A few incipient drainage courses carry water only during or shortly after heavy rains. Most of the moisture is absorbed as soon as it falls. Internal drainage is adequate and probably would continue to be so after irrigation.

This soil should be easy to cultivate, and if it is properly handled very little difficulty from surface blowing should be experienced. Whitlock loamy sand, deep phase, would require a moderate amount of irrigation water but not nearly so much as Superstition loamy sand. With proper rotation, use of green manures and cover crops, and careful management to prevent blowing, this soil would be well adapted under irrigation to the production of most crops suited to this section.

Whitlock loamy sand, eroded phase.—This soil resembles typical Whitlock loamy sand, but owing to erosion of the surface soil, the gravelly subsoil is generally closer to the surface. In many places many particles of small well-rounded gravel form a desert pavement on the surface. Most of the particles of gravel appear very dark brown or black on the top or exposed surfaces, but they have a highly mixed mineralogical origin and different colors when freshly fractured. In general, the topmost 8 to 24 inches of soil is light reddish-brown mildly or moderately calcareous rather loose loamy sand. At various depths, but averaging about 12 inches, the material is light reddish-brown slightly coarser textured loamy sand or sand and contains many gray nodules of lime. This material generally continues to a depth of about 20 inches, where it is underlain by brownish-gray gravelly and sandy material with a pale-red tint, which is so much cemented that a pointed iron bar is necessary when digging it. Lime apparently is the principal cementing material of this layer. The cemented layer is only a few inches thick in some places but is 2 feet or more thick in other places. It is underlain abruptly by loose very highly calcareous well-rounded gravel and sand.

Large bodies of this soil occur in the southwestern and south-central parts of the area. The soil in the five small bodies in the southeastern part does not conform to the soil described above. Here, the desert pavement is lacking and the soil has been derived from granitic material washed from the Gila Mountains, whereas the soil in most of the other areas has developed mainly from alluvial terrace deposits of the Colorado River. The upper part of the soil profile closely resembles that of the typical areas, but the lower part of the subsoil consists of angular gritty sand and coarse sandy materials. These areas also occupy distinct ridges that are from 15 to 36 inches above the general level. Soil on these ridges might be developed agriculturally and used for the production of most irrigated crops grown in this section. Elsewhere the relief either is too rough or is so rolling that considerable ditching or leveling would be necessary to prepare the land for irrigation, and the presence of porous gravelly sediments close to the surface makes such development impracticable. With possible minor exceptions, the soil is unsuited to development under irrigation.

Whitlock sand.—In its very loose surface soil and hummocky relief, Whitlock sand is similar to the hummocky phase of Superstition sand. To a depth of about 8 inches the material is light-brown loose noncalcareous sand. Between depths of 8 and 30 inches it is light-brown friable or loose mildly calcareous loamy sand. This material is underlain to a depth of 45 inches by light reddish-brown weakly cemented light-textured sandy loam with many irregular-shaped but somewhat rounded nodules of carbonate of lime. This material, in turn, is underlain by light reddish-brown fine sandy loam that contains many lime nodules and much small rounded or subangular gravel of mixed mineralogical origin. The material in this layer is more firmly cemented, and in most places an iron bar is necessary when digging. It continues to an average depth of about 60 inches, where, in many places, light reddish-brown loose and porous highly calcareous sandy or gravelly parent materials occur. In other places, however, especially in the central and east-central parts of the area,

the subsoil below an average depth of 60 inches is underlain by pale reddish-brown moderately cemented heavy sandy loam or light sandy clay loam, in which the red color is more strongly developed when moist. Gray or white splotches and flecks of lime are present. This material resembles the subsoil of the Mohave soils and represents an old developed soil layer that has been buried by the materials from which Whitlock sand has developed.

The soil occurs in the north-central and western parts of the area. In addition to being somewhat hummocky, the surface is somewhat rolling or ridged in some places. The parent material consists mainly of the Colorado River terrace and wind-deposited materials, although in many places in the east-central and central parts of the area the soil has developed largely from alluvial deposits washed from the Gila Mountains. Drainage conditions appear to be favorable or excessive, and it is probable that poor drainage would not develop under irrigation. The typical vegetal cover consists of galleta grass, bursage, and some creosotebush.

It seems probable that some bodies of this soil may be leveled and developed agriculturally. Considerable expense would be required, however, to level the hummocks, which in many places are as much as 3 feet high, and control of blowing of the sandy surface soil would be difficult under cultivation. In localities where the heavier (Mohave) subsoil occurs, the land probably could be farmed with fair success, but in other places the use of a very large quantity of water could hardly be avoided. A large quantity of manure or green vegetable matter should be supplied the soil so as to furnish organic residues and provide a more desirable surface soil.

Whitlock sand, dune phase.—The lower part of the profile of Whitlock sand, dune phase, is practically identical with that of typical Whitlock sand, but the loose wind-shifted surface covering is thicker, and the sand is blown up into low dunes instead of hummocks. The dunes range from about 3 to 5 feet above the intervening depressions. Some of them are rounded and others, which are elongated, range from about 5 to 20 feet in width.

The comparatively small bodies of this soil are in the southwestern part of the area. The vegetation consists largely of a spare stand of galleta grass, with a few scattered shrubs, principally jointfir, or Morman tea. The expense of leveling and preparing this rough land for irrigation would be great and probably prohibitive.

Whitlock gravelly sandy loam.—Whitlock gravelly sandy loam, like some other soil types of the Whitlock series, has two kinds of parent material—deposits near the Gila Mountains, largely of granitic origin, and old terrace deposits of the Colorado River, of highly mixed lithological character. The surface is covered by a desert pavement (pl. 1, *A*), which, near the mountains, is composed largely of angular granitic gravel and farther west consists of well-rounded gravel of highly mixed mineral character. Beneath this pavement and continuing to a depth of about 8 inches is light reddish-brown or pale reddish-brown firm but friable moderately calcareous gravelly sandy loam.

Near the mountains the surface soil is underlain to a depth of about 26 inches by pale reddish- or grayish-brown somewhat cemented gravelly sandy loam. When dry this layer is difficult to dig with a

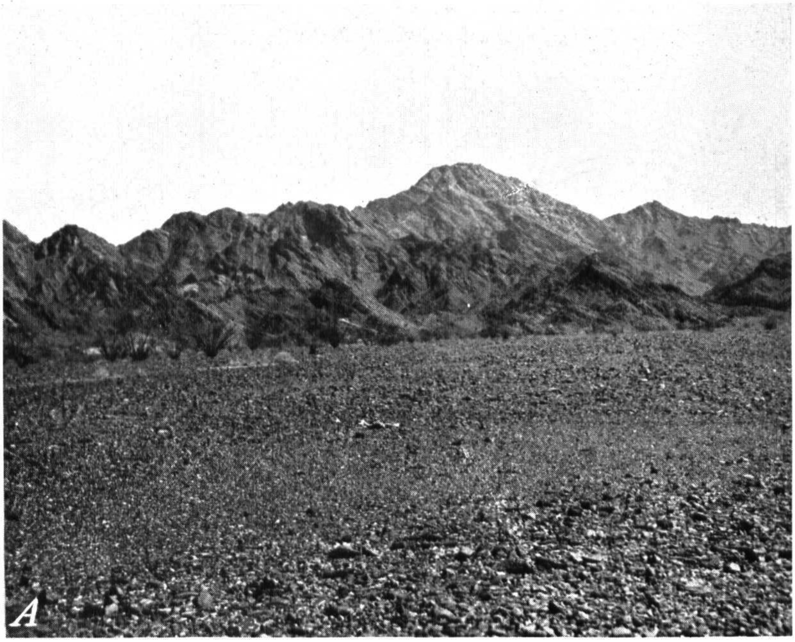
shovel but is easily broken with a bar. It is underlain by reddish-brown or pinkish-brown gravelly loam that has a higher content of colloidal material and is also somewhat more firmly cemented than the layer immediately above. This material continues to a depth of about 40 inches, below which is highly calcareous reddish-gray lime-cemented gravel, coarse sand, and sand. It is so cemented that a bar is necessary when digging, but it does not contain quite so much lime as the layer above. Comparatively loose porous moderately calcareous light reddish-brown gravel and coarse sand lie about 5 feet below the surface. The particles of gravel and sand are angular and are mainly granitic in origin.

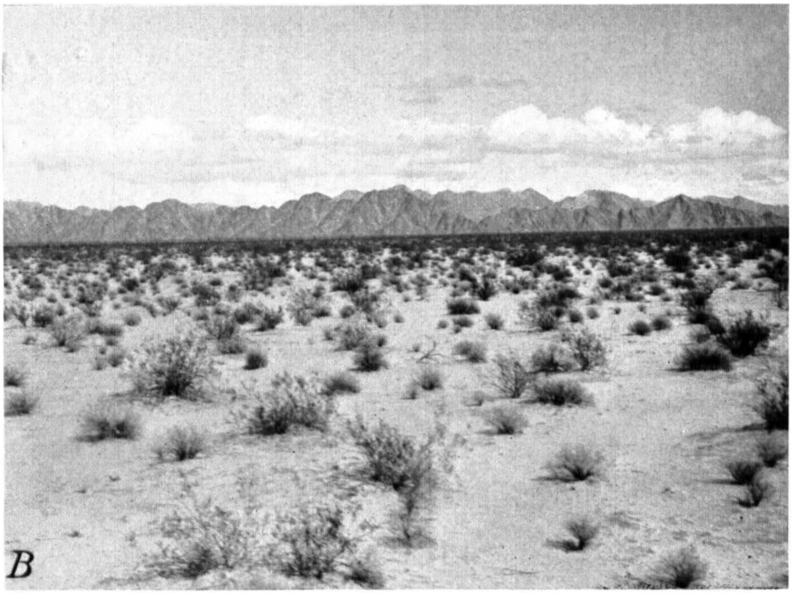
Farther from the mountains, where the soil has developed largely from old Colorado River terrace materials, the material between depths of about 6 and 26 inches is gray rather firm and softly cemented well-rounded lime-coated gravel and sand of rather highly mixed mineralogical origin. It is underlain to a depth of about 46 inches by softly cemented gravel and sand. This layer is highly calcareous but does not contain nearly so much lime as the layer immediately above. Between depths of about 46 inches and 6 feet is light reddish-brown mildly calcareous well-rounded gravel and sand that are firm or softly cemented to such a degree that the sides of a newly made excavation do not cave. The materials, however, may be easily broken apart with a shovel. The cementation and content of lime decrease gradually with depth, and about 12 feet below the surface the gravelly material is clean and very mildly calcareous and caves badly. This soil, developed mainly from Colorado River terrace sediments, is more severely eroded than elsewhere, and the zone of highest content of lime, therefore, is closer to the surface than in the bodies near the mountains.

Whitlock gravelly sandy loam occurs in many bodies in the northern and north-central parts of the area. It is the second most extensive soil in the area. In general the surface is smooth, but it is decidedly rolling in some places and rough in others. External drainage is well developed, and the porous subsoil would provide adequate internal drainage for much more water than the soil now receives. The steep, rough, unfavorable relief, however, is such that development for irrigation is not feasible. The native vegetation consists mainly of a sparse stand of ocotillo, species of cacti, and an occasional creosotebush.

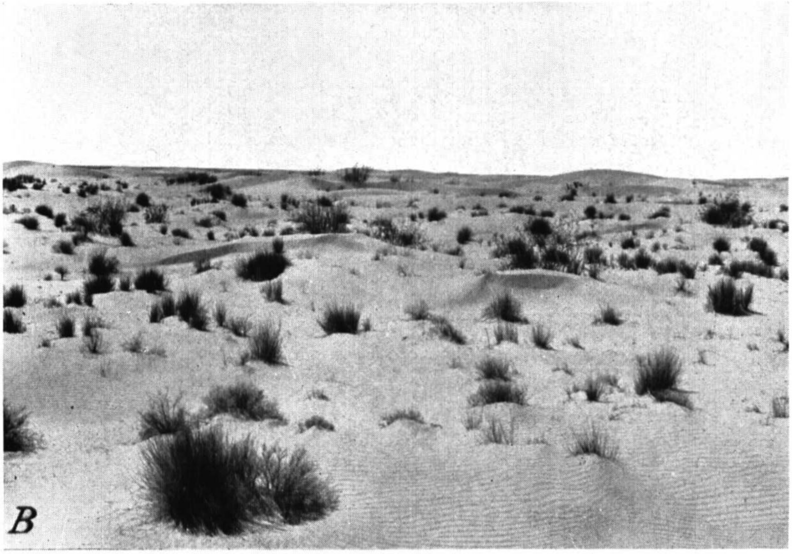
Whitlock gravelly sandy loam, dune phase.—The lower part of the profile of Whitlock gravelly sandy loam, dune phase, is identical with that of the typical soil, but superimposed over this are aeolian deposits of pale reddish-brown or grayish-brown very mildly calcareous sand and fine sand that have blown into low dunes. These dunes range from 2½ to more than 6 feet in height and from a few to more than 20 feet in width. Most of the sand has blown from nearby sandy soil areas, is of granitic origin, and is high in siliceous material.

Several bodies of this soil are in the northwestern part of the area, and a few are in the north-central and west-central parts. It covers a small total area. The relief is even rougher and more adverse than that of typical Whitlock gravelly sandy loam, and agricultural development under irrigation is impracticable. The dune





A, Desert pavement on Whitlock gravelly sandy loam. Gila Mountains in distance. *B*, Native vegetation of creosotebush and bur-sage on Superstition sand, hummocky phase.



A, Scattered growth of creosotebush and galleta grass on Cajon loamy sand; *B*, characteristic vegetation—creosotebush and galleta grass—on dune sand, low-dune phase.

areas support little vegetation other than a few bunches of galleta grass, and probably they will always be a source of blow sand during periods of high winds.

SUPERSTITION SERIES

A large part of the Superstition soils has developed from old Colorado River terrace sediments, from wind-deposited materials, or from a combination of these materials. The individual particles of the wind-laid deposits and, to less degree, the Colorado River terrace sediments are more rounded and more siliceous than the alluvial-fan deposits formed by materials washed from the Gila Mountains. The development of a profile of the Superstition soils is incipient, as compared with that of the Whitlock and Mohave soils. The surface soils consist of light reddish-brown or pale reddish-brown mildly calcareous loose or very friable single-grained material. The subsurface layers differ from the surface soils only in being slightly firmer and slightly more calcareous. The subsoils consist of pale reddish-brown or pinkish-gray very weakly cemented material and contain many irregular-shaped lime nodules. This layer is underlain by loose mildly calcareous sandy parent material.

Superstition loamy sand.—The topmost 8 inches of Superstition loamy sand is light reddish-brown or light pinkish-brown somewhat firm or coherent loamy sand. About 60 percent of the coarse sand and small gravel that occur on the surface appears to be of granitic origin, having been transported from the Gila Mountains; but the rest consists of well-rounded pebbles of mixed mineralogical composition, having come from the Colorado River terrace deposits. Between depths of about 8 and 36 inches the soil material is very similar to that immediately above but contains less coarse material and slightly more colloids and is mainly a loamy sand in texture. Both the surface soil and this layer are mildly calcareous. Between depths of 36 and 50 inches is pale reddish-brown slightly compact or very weakly cemented loamy sand containing many irregular-shaped or rounded gray or white lime nodules. This layer contains slightly more colloids than the layer immediately above. Beneath this layer are loose sand and fine gravel of mixed mineralogical origin. This parent material is very low in colloids and ranges from moderately to highly calcareous.

Several bodies of this soil occur chiefly in the northern part of the area, but their total area is not large. The surface generally is smooth and gently sloping. Many of the bodies occupy depressed or valleylike positions where the mineral material has been derived partly from rock fragments washed from the Gila Mountains and in part from old terrace sediments deposited by the Colorado River. As in most other soils of this area, external drainage is well developed and internal drainage is excellent or excessive. The soil absorbs the greater part of the rain as rapidly as it falls. The native vegetation consists mainly of bur-sage, creosotebush, and galleta grass.

None of the soil has been cultivated, but under irrigation it should respond very much the same as Superstition sand. It should be easier to handle, however, and, owing to its heavier texture, should produce slightly heavier crop yields than Superstition sand.

Superstition sand.—The topmost 6 inches of Superstition sand is light reddish-brown loose mildly calcareous sand that is very slightly loamy in texture. Below this layer and extending to a depth of about 20 inches the soil material differs only in that it is somewhat firm. This layer is underlain by material of similar-colored somewhat firm but friable moderately or highly calcareous loamy sand. A few small irregular-shaped lime nodules are present. Below this and continuing to a depth of 45 inches is pale reddish-brown firm or weakly cemented but friable loamy sand containing a few gray or white lime flecks and small irregular-shaped nodules. This is underlain to a depth of about 60 inches by light reddish-brown heavy loamy sand containing many gray or white irregular-shaped but somewhat rounded lime nodules. The material in this layer is weakly cemented and rather high in lime. It is more difficult to dig with a shovel than the material in other layers, but when wet it becomes loose and may be very easily dug with a shovel. Below this and continuing to an undetermined depth is loose light reddish-brown moderately or highly calcareous sand, with a few small rounded gravelstones, of mixed mineralogical origin.

Although this soil does contain soluble mineral plant nutrients, it is very low in organic matter or nitrogenous substances. The soil is very porous, and, following the development of irrigation, the soluble nutrients might be rapidly leached out.

One large body of this soil is in the west-central part of the area, several small ones are near the northwestern and western boundary, and a small one is in the south-central part. The surface of this soil type is generally smooth and very gently sloping, and, although a few small sandy hummocks occur in places, they are not large enough to be difficult or expensive to level when preparing the land for irrigation. Under desert conditions, the soil absorbs most of the rain as rapidly as it falls. Following the development of irrigation, internal drainage would be free or excessive, owing to the coarse sediments and porous condition of both solum and substratum. The native vegetal cover consists largely of a sparse stand of bur-sage and creosotebush, with galleta grass occupying small sandy hummocks. Short-lived grasses and flowering plants are conspicuous after spring rains.

No irrigation or agricultural enterprises have been developed in the area, but near Yuma this type of soil is irrigated and is used for the production of grapefruit and oranges. On the Yuma Mesa Experimental Farm of the University of Arizona, oranges, grapefruit, dates, and alfalfa are grown on this type of soil. Other data relating to irrigation, crops, water requirements, and yields on this soil are given in the section on Land Uses and Soil Management.

Superstition sand, hummocky phase.—The hummocky phase of Superstition sand has a loose surface layer of wind-drifted medium sand and fine sand that has blown into hummocks ranging in height from about 18 inches to as much as 3 feet in places. The topmost few inches consists of light reddish-brown mildly calcareous loose sand and overlies material that differs only in being slightly more firm—sufficiently so to keep the sides of excavations from caving badly. Between depths of about 20 and 40 inches the soil material is very similar to the material above but differs in being somewhat

firmer, which indicates a slightly higher concentration of soluble cementing substances. Below this and continuing to a depth of about 58 inches is light reddish-brown firm but friable moderately or highly calcareous loamy sand, together with a few small irregular-shaped but somewhat rounded lime nodules. This material is underlain to a depth of about 76 inches by light reddish-brown weakly cemented highly calcareous loamy sand containing some coarse sand, some fine gravel, and many irregular-shaped lime nodules. Beneath this the parent material is only very slightly firm mildly calcareous light reddish-brown sand. In some places a more compact pinkish-brown loam or light clay loam lies below a depth of 5 feet. This material is similar to the soil material of Mohave sandy loam and probably represents a buried soil. Where this buried soil occurs within 6 feet of the surface, the quality of the soil is better than in other locations where the substratum is excessively porous.

This is the most extensive soil in the area, covering 19,456 acres. Large bodies are in the northwestern, west-central, and southwestern parts, and smaller ones occur throughout the area. Most of this soil occupies a generally level, gently sloping, or, in places, slightly rolling plain. Considerable expense would be required to level and prepare such land for irrigation.

The parent material has come from different sources. In some places it is largely from old Colorado River terrace sediments. In other places most of the material has been eroded from the Gila Mountains and later deposited as fan alluvium. In many places the upper part, ranging from 1 to 3 feet in thickness, consists of wind-drifted fine or medium sand, the geological origin of which may have been far from the area. The loose sandy material of the hummocks contains some dark-colored particles, but the largest part is light-colored and highly siliceous. The predominant vegetation is a scant growth of creosotebush and bur-sage (pl. 1, *B*) in the smoother districts and galleta grass in the sandier or more hummocky areas. Following spring rains, a number of grasses, weeds, and flowering plants are conspicuous.

None of this soil has been irrigated, but a few tracts have been leveled, probably in connection with proving up homestead claims. When the grass and brush are cleared from this soil, the surface sand will blow and drift; therefore great care should be exercised when preparing the land for irrigation.

This soil is rather loose and open to a depth of 8 feet or more. With careful management it could possibly be used for the production (under irrigation) of citrus fruits, dates, alfalfa, melons, and some of the winter vegetables, but distribution and seasonal use of water would be very difficult, and great care would be necessary to prevent crop damage from blowing sands. The soil is very low in organic matter and would need to be enriched by plowing under green-manure cover crops or by the use of organic manures. Recommendations given in the section on Land Uses and Soil Management relating to the use of commercial fertilizers on Superstition sand apply also for this soil. Water requirements would be as great as and might exceed those given for the different crops grown on Superstition sand.

ANTHONY SERIES

As mapped in this area, the Anthony soils are not so red nor so well developed as the typical Anthony soils mapped elsewhere in southern Arizona. The soils do not differ greatly from the Cajon soils, but they have somewhat more mature profiles and would be better agricultural soils if they were irrigated. The surface soils are light brown or pale reddish brown and noncalcareous or very mildly calcareous. The subsoils are firm or very slightly cemented and contain fine veins of gray carbonate of lime. The lower subsoil layers or substrata consist of loose mildly calcareous angular sandy and gravelly material similar to the surface soils. The soils have developed mainly from comparatively recent granitic alluvial-fan deposits of material washed from the Gila Mountains.

Anthony fine sand.—The topmost 8 inches of Anthony fine sand is light reddish-brown very mildly calcareous or noncalcareous very friable micaceous fine sand, in which the red tinge is most pronounced when moist. Although this material is somewhat firm or coherent and does not cave from a newly cut bank, it readily crumbles to a structureless single-grained mass. Below this layer is very similar material, although it is mildly calcareous and contains a slightly higher percentage of medium sand. Between depths of about 30 and 50 inches is firm but friable moderately calcareous heavy loamy sand or sandy loam. The material in this layer is slightly firmer or very weakly cemented and contains carbonate of lime in fine veins or seams. In some places this material is underlain by slightly coarser textured loose mildly calcareous sharp angular granitic materials, and in other places it is underlain by material similar to that of the subsoil of Mohave loamy sand.

One body only, including 4,480 acres, is mapped about 6 miles southwest of Fortuna mine. The surface is smooth and very gently sloping. In places there are small hummocks ranging from 4 to as much as 18 inches in height, where fine sand has accumulated around clumps of creosotebush.

The native cover includes creosotebush, bur-sage, galleta grass, several kinds of cacti, and a few paloverde and mesquite trees. Drainage is adequate under desert conditions, and it is not believed that irrigation would result in development of poor drainage. This soil is of fairly favorable texture and structure for the production of crops under irrigation and would be moderately well adapted to such crops as can be grown in this section. It is too sandy and porous to be ideal, and doubtless much water would be lost by deep percolation.

Anthony loamy sand.—Anthony loamy sand to a depth of about 6 inches is reddish-brown micaceous loose very mildly calcareous or noncalcareous loamy sand. The sand particles are both angular and rounded and predominantly of quartz. Between depths of about 6 and 18 inches is light-brown or reddish-brown micaceous mildly calcareous firm but friable loamy coarse sand. This is underlain to a depth of about 40 inches by material similar in color and texture but moderately calcareous and firmer or slightly more compact. Below this is similarly colored loose moderately or mildly calcareous loamy sand. In many places this rests at a depth of 5 feet or more below

the surface on reddish-brown comparatively compact sandy loam material similar to the subsoil of Mohave loamy sand.

Most of this soil is in the southeastern part of the area, although one body is near the northern margin and one is about 4½ miles west of Fortuna mine. The surface is smooth and gently sloping. The predominating native vegetation is creosotebush. Internal and external drainage are good to somewhat excessive. In places where the heavier substratum occurs, the water requirement should not be exceptionally high if the land were properly irrigated, but in other places it will be high. The soil should be fairly well adapted to deep-rooted crops and to the production of most of the irrigated crops grown in this section.

CAJON SERIES

The Cajon soils occur on recent alluvial flood plains formed by intermittent streams that originate in the Gila Mountains and extend into the alluvial fans a few miles from the lower reaches of the mountains. The soil consists largely of light-brown loose and porous granitic materials that are sharp, micaceous, and slightly calcareous. The subsoils and substrata generally are coarser textured and more porous than the surface soils.

Cajon loamy sand.—The topmost 12 inches of Cajon loamy sand is pale reddish-brown loose mildly calcareous loamy sand. Below this the material is slightly more calcareous and not quite so loose. Beginning at a depth of 30 inches is light brownish-gray friable moderately calcareous loamy coarse sand that contains slightly less colloids than the layer above. This material rests at an average depth of about 48 inches on light brownish-gray mildly calcareous loose coarse sand containing some fine gravel and a few large gravelstones. The entire soil is developed mainly from granitic material and is slightly micaceous.

Small bodies of this soil parallel Fortuna Wash in the northern part of the area. Others lie about 5 miles northwest of Fortuna mine, another about 4 miles south of Fortuna mine, and two are near the southeastern margin of the area. Most of these bodies adjoin channels of intermittent streams. The surface is smooth and very gently sloping. In some places the vegetal cover is mainly creosotebush, and in other places creosotebush, ocotillo, bur-sage, and some galleta grass are common (pl. 2. *A*). In many places creosotebush grows from 6 to 8 feet high. In places it is apparent that this soil is flooded at times under natural desert conditions, but, following development of irrigation and protection from surface drainage waters, both external and internal drainage should be adequate; in fact, internal drainage generally is excessive. In some places where the deeper substratum is similar to that of Mohave loamy sand, the water requirement of this soil should not be too great. Elsewhere, the porous subsoil is deficient in water-holding capacity, and very careful irrigation and large quantities of water probably would be required.

Cajon loamy coarse sand.—Typical areas of this soil to a depth of about 18 inches consist of light brownish-gray micaceous firm but friable mildly calcareous loamy coarse sand. Beneath this the material differs only in being slightly less loamy. Below a depth

of 44 inches the material is slightly coarser in texture, slightly looser, and slightly less loamy than the material above. Beginning at an average depth of 60 inches and continuing to a variable depth of more than 6 feet are light-gray micaceous very mildly calcareous coarse sand and fine gravel.

Bodies of this soil, a few miles south of Fortuna mine, do not aggregate a large total area. The surface is smooth and gently sloping. It is cut by shallow drainage channels in places, but these would not be difficult to level when preparing the land for irrigation. Surface drainage is adequate, and internal drainage is excessive. The predominant vegetal cover includes several kinds of cacti, creosotebush, and bur-sage.

Although crops could be produced on this soil after development of irrigation, the soil is so porous that the water requirements would be unusually high.

Small areas with a fine-textured subsoil, lying about 5 or 6 miles south of the Fortuna mine, are included in mapping. In that district the surface soil is underlain at a depth ranging from 24 to 40 inches by light-brown comparatively fine textured moderately calcareous loamy sand, fine sand, or fine sandy loam, which generally continues to a depth of 6 or more feet. The presence of these sediments greatly improves the moisture-retaining capacity of the included soil over that of typical Cajon loamy coarse sand, which has a loose coarse-textured subsoil. This included soil, therefore, will not require nearly so much irrigation water as the typical soil. If it is developed, care should be exercised in irrigation in order to avoid excessive use and waste of water. Owing to the coarse texture of the surface soil, however, green manure or the addition of other organic matter would be highly beneficial.

Cajon sand.—The topmost 10 inches of Cajon sand is light grayish-brown or brownish-gray loose mildly calcareous somewhat micaceous sand. Beneath this and continuing to a depth of 5 feet or more is gray mildly calcareous fine gravel and sand. Though this lower material is rather loose, it does not cave badly in a newly cut bank. In some places at a depth of about 5 feet or slightly deeper is a substratum consisting of an old buried soil resembling Mohave loamy sand. Where this occurs, the soil might have some value for farming under irrigation, but elsewhere the loose porous subsoil and substratum would require so much water that it is doubtful if returns would repay the cost of production.

The soil occurs principally in the wide stream bottoms northwest and southwest of Fortuna mine and in the extreme southeastern part of the area. It is associated with Cajon loamy sand, generally where floodwaters are common after periods of heavy rainfall. After the development of an irrigation project in this area, it is probable that such floodwaters would be controlled before they reach the irrigated lands. The native vegetation includes creosotebush and galleta grass, in addition to paloverde, ironwood, and mesquite trees along stream channels. The total area mapped is very small.

Cajon sand, hummocky phase.—Areas of Cajon sand that have a hummocky relief are classified as Cajon sand, hummocky phase. The hummocks range from 12 to 30 inches in height and consist of loose somewhat angular and rounded particles of wind-laid light-brown

or grayish-brown medium sand and fine sand, which are mildly calcareous in places. Beneath the hummocks is a 15-inch layer of grayish-brown rather loose mildly calcareous sand. This is underlain by very similar angular sandy sediments or by slightly coarser textured sandy and fine gravelly material.

This soil, like Cajon sand, occurs in wide-bottomed stream channels and in recent flood plains of intermittent streams where recently deposited materials have accumulated. Bodies of this soil are about 6 and 8 miles, respectively, northwest of Fortuna mine; one large body is about 4 miles southwest of the mine, and one is at the international boundary in the southeastern part of the area. The soil is not extensive.

The surface is very hummocky, but the soil lies in a gently sloping or nearly level plain. The parent material consists largely of angular granitic material, and the subsoil generally is so open that the soil is not well suited to development for irrigation and production of crops.

Cajon fine gravelly sand.—The topmost 10 inches of Cajon fine gravelly sand consists of light brownish-gray loose mildly calcareous micaceous fine gravelly sand and loamy sand. This material is underlain by a layer of black and gray mildly calcareous angular granitic micaceous sand and fine gravel, which reaches to a depth of 6 feet or more. This soil is very loose and open in most places, although in some places layers of slightly firmer loamy material occur. Everywhere, however, the soil is loose and porous.

Several small bodies occur in the northeastern part of the area, and others lie from 2 to 5 miles south of Fortuna mine. The total area is small. The surface is smooth and gently sloping, external drainage is adequate, and internal drainage is excessive. Owing to the coarse-textured subsoil and substratum, this soil would require excessive quantities of water if it were irrigated. It is not very desirable for irrigation and probably could not be used successfully for the production of crops.

MISCELLANEOUS LAND TYPES

Dune sand.—Dune sand occurs mainly in one large body in the south-central part of the area and includes dunes rising from 5 to 25 feet above the intervening land. The soil profile on the top of the dunes is very similar to that in the areas between dunes. The material consists of grayish-brown well-rounded clean sand and fine sand, containing both gray and dark grains, though the lighter colored siliceous material predominates. It is either very slightly calcareous or without sufficient free lime to effervesce with dilute hydrochloric acid. The dunes are almost barren of vegetation, but in some low places between them a few green woody shrubs reach a height of about 30 inches, and, in a few places, 48 inches. The shrubs are jointfir, or Mormon tea.

The sand of the dunes is probably derived largely from local sandy materials of the Superstition and other sandy soils lying between the Gila Mountains and the Colorado River, although part of it may have been carried from sandy areas west of the Colorado. The prevailing winds, especially those of highest velocity in the spring, are from the northwest; and the area of dunes appears to be progressing south-

eastward. The sand shifts with almost every moderate wind. It would not be practicable to irrigate any of the dunes for the production of crops.

Dune sand, low-dune phase.—The origin, character of material, and mode of formation of dune sand, low-dune phase, is identical with that of typical dune sand, but the dunes are not so high, they support a greater growth of plants, and, although they are almost constantly shifting, they do not move so rapidly as the typical dune sand.

A large body extends from the central part of the area southward to the international boundary, two small bodies are near the northern margin of the area, and several very small bodies are elsewhere throughout the area. This land type is extensive. The dunes rise from 3 to 5 feet above the intervening depressions. The vegetal cover consists of a sparse stand of galleta grass, creosotebush, and jointfir (pl. 2, *B*).

An unfavorable relief, the loose leachy character of the material, and the difficulty of controlling sand blowing preclude the feasible irrigation of these low dunes.

Rough broken and stony land (Whitlock soil material).—Rough broken and stony land (Whitlock soil material) includes stony and gravelly alluvial-fan remnants that have been badly cut by gullies and stream courses. The soil material is mainly of the Whitlock series, although part of it is rather more recent in deposition and development of a profile. Almost everywhere, however, is a surface covering of nearly black gravel forming a desert pavement. The parent material has been washed from the Gila Mountains and is largely granitic, although an admixture of other igneous rocks is common. A sparse stand of ocotillo and a few creosotebush and bursage plants constitute the vegetation on the fans. Paloverde, ironwood, and mesquite trees grow in or along the eroded stream channels.

Owing to excessive stone and gravel content, loose leachy character of the soil, and adverse relief, it would not be practicable to develop this soil for the production of irrigated crops.

Rough stony land.—Rough stony land includes rough almost barren mountainous areas and buttes that have practically no soil covering and support but little vegetative growth. The land has no agricultural value and its value for grazing purposes is negligible.

Riverwash.—Riverwash consists of the loose sandy, gravelly, and stony materials in the beds of intermittent stream and drainage channels. The material is coarse, loose, and leachy and is subject to overflow and shifting of materials after periods of heavy rainfall. It is of no value for irrigation purposes but supports a little grazing. A few paloverde, ironwood, and mesquite trees, catclaw, galleta grass, and species of cacti form a scattered stand over much of the material.

LAND CLASSIFICATION

The Yuma Desert area consists entirely of desert land. As none of it is cultivated, a classification of the land as to its suitability for the production of crops under irrigation must rest largely on a consideration of the physical characteristics of the soils or land and observations concerning irrigation farming on more or less similar soils of this section.

The suitability of the land for irrigation depends principally on (1) the potential productivity of the soils under feasible systems of management, and (2) the cost of production and marketing, including water supply, equipment, labor, fertilizers, and transportation. Two factors that affect both productivity and cost of production need special consideration in this area. They are the feasibility of controlling soil blowing (wind erosion) and the cost or feasibility of distributing water. Both the control of blowing and the distribution of water are very difficult on extremely loose sandy soils such as those that occupy a large part of the Yuma Desert area. Still another factor that needs consideration, although it may be considered a part of the cost of production, is the efficiency of water utilization; that is, how much water actually will be used on the land—not the water requirement of the plants, but the entire quantity used, including that lost by deep percolation and evaporation.

The physical soil characteristics affecting productivity, stability, and ease or cost of irrigation are the lay of the land and the depth, texture, structure, porosity, consistence or coherence, drainage, and water-holding capacity of the soils. Productivity depends also on the chemical characteristics of the soils, but these do not differ so greatly here as do the physical characteristics. All the soils are poor in organic matter and nitrogen, and all are comparatively rich in lime and other bases, but the sandier soils are poorer than those having loamier textures.

None of the soils of the Yuma Desert area is outstandingly fertile or has high water-holding capacity, and therefore none can be considered ideal for irrigation. The better soils, however, have fairly favorable physical characteristics and are considered in this classification as moderately well suited to irrigation. The absence of silt in the irrigation water will make it impossible to build up these soils by silting as has been done in the Yuma Valley and parts of the Yuma Mesa. Great distance to the large markets and high cost of water supply are added handicaps.

Based on these factors, the soils of the area are grouped in four classes as follows: Soils moderately well suited to irrigation, soils rather poorly suited to irrigation, soils very poorly suited to irrigation, and soils unsuited to irrigation.

SOILS MODERATELY WELL SUITED TO IRRIGATION

The soils moderately well suited to irrigation are the most desirable soils of the area. These soils are deep, easy to cultivate, well drained, free from harmful accumulations of saline and alkaline salts, probably not subject to severe soil blowing, not excessively porous or leachy, and free from hardpan or impervious clay. The lay of the land is such that a minimum of expense will be required to level or to prepare it for irrigation. These soils are, however, sandier, less fertile, and of lower moisture-holding capacity than the best soils of most successful irrigation sections and probably should not be considered more than moderately well suited to irrigation. These soils probably would make more efficient use of the water supply than most of the other soils, but, because they would require rather frequent irrigation with considerable waste through evaporation and deep percolation, they are not ideal from this point of view.

The following soils in order of their relative preference are placed in this group: Mohave loamy sand, Mohave loamy coarse sand, Anthony fine sand, Anthony loamy sand, Whitlock loamy sand, shallow phase (over Mohave soil material), and Whitlock loamy sand, deep phase. These soils comprise a total area of 37,824 acres, or 21.7 percent of the area.

SOILS RATHER POORLY SUITED TO IRRIGATION

Soils of the second group are rather poorly suited to irrigation and production of crops because of the open leachy character of the soil and substrata and in part because of the coarse texture of the surface soil, which would be subject to blowing and wind erosion if the land were cleared for cultivation. Probably they are also somewhat less fertile than the soils of the better class described above and would make less efficient use of the water supply. Distribution of water on these porous sandy soils would be rather difficult.

The soils of this group, in order of quality, are: Superstition loamy sand, Cajon loamy sand, Superstition sand, Whitlock loamy sand, and Cajon loamy coarse sand, which comprise a total of 23,808 acres, or 13.7 percent of the area.

SOILS VERY POORLY SUITED TO IRRIGATION

The soils of the group designated as very poorly suited to irrigation are considered undesirable for that purpose because of their porous sandy character, their tendency to blow, and the probable difficulty of distributing water upon them without excessive loss by deep percolation. Whitlock sand is the only member of the group that has even moderately fine textured layers in the subsoil, and, with its sandy porous surface layer, it probably would allow too rapid percolation. Whitlock sand, Superstition sand, hummocky phase, and Cajon sand, hummocky phase, have very loose surface soils, very uneven and hummocky relief, and a tendency to shift frequently in the wind. The expense of leveling and preparing the land for irrigation would be relatively great, and, if cleared, the soils doubtless would blow very badly. Small areas of Superstition sand, hummocky phase, on the Yuma Mesa have been cleared and cultivation has been attempted, but drifting sand has covered young crop plants and cut off tender shoots of plants. So far as is known, there is no instance of this soil having been successfully farmed. The following soils are included in this group: Whitlock sand; Superstition sand, hummocky phase; Cajon sand; Cajon sand, hummocky phase; and Cajon fine gravelly sand. They cover a total area of 35,584 acres, or 20.4 percent of the area.

SOILS UNSUITED TO IRRIGATION

Soils designated as unsuited to irrigation have some condition that makes the development of agriculture under irrigation obviously infeasible or not worth the required expenditure of labor and other costs. Soils are placed in this group because of rough lay of the land or adverse physical characteristics, such as excessive porosity, leachiness, shallowness, or stoniness. The soils included in this group are Whitlock loamy sand, eroded phase; Whitlock sand, dune phase;

Whitlock gravelly sandy loam; Whitlock gravelly sandy loam, dune phase; Mohave gravelly sandy loam; dune sand; dune sand, low-dune phase; rough broken and stony land (Whitlock soil material); rough stony land; and riverwash. Bodies of these soils aggregate 76,864 acres, or 44.2 percent of the area.

LAND USES AND SOIL MANAGEMENT

None of the area covered was cultivated or used for agricultural purposes at the time of this survey. The native vegetation includes creosotebush, galleta grass, and bur-sage as the principal perennial plants that grow on most soils of the area. Many varieties of cacti grow on the fan slopes, and paloverde, ironwood, and mesquite trees grow adjacent to intermittent stream channels. After spring rains, evening-primrose, verbena, and other less conspicuous flowering plants grow and remain green a few days, or for periods of weeks if sufficient rain falls. If more than the usual quantity of rain falls in the spring, a 6-weeks grass and a plantain make appreciable growth. None of these plants is grazed at present, because there is no water available for livestock. Coyotes, foxes, gophers, lizards, and snakes thrive under the present desert conditions.

Soils very similar to those of this area have been irrigated near Yuma and in other parts of southern Arizona.

At the Yuma Mesa Experimental Farm, Superstition sand[7] has been irrigated and is used for the production of grapefruit, oranges, dates, and alfalfa. The following data have been obtained from G. H. Seamans, superintendent.

Irrigation of trees is both in checks and in furrows. Flooding between borders is practiced where alfalfa is grown. Large heads of water and short runs are essential on this sandy soil. Alfalfa will probably require 15 acre-feet the first year after planting on virgin land and from 9 to 12 acre-feet each year thereafter.

The duty of water for alfalfa planted on an acre that had previously been cultivated and was well silted from use of muddy irrigation water was 9 acre-feet. The duty of water for alfalfa on the newly developed mesa lands probably would be about 12 acre-feet, as the water used for irrigation would be practically free from silt and hence the soil would not be built up as it has been on the Yuma auxiliary project.

Best practices at present appear to be to irrigate alfalfa once a week during June and July. The main purpose of these frequent irrigations is to keep soil temperatures down in the topmost 12 inches of soil. For this purpose the most efficient irrigation will be obtained with a rapid flooding of the ground, which can best be accomplished by using a large head of water, short runs, and grading to a considerable slope.

Yields should approximate those on the experimental farm, where cuttings from May 13 to December 1 yielded about 1,950 pounds of hay from an acre of unfertilized land and about 6,150 pounds from an acre treated with about 5 tons of barnyard manure. These yields are for the first year's crop and should increase the second year. It is possible to cut hay once about every 5 weeks, or, if not cut for

[7] See footnote 2, p. 1.

hay continuously, a crop of seed may be harvested in July and another in September. The fact that the yield of alfalfa from the manured plots was more than triple that cut from the unfertilized plots indicates clearly the need of nitrogenous material. This probably can best be supplied by plowing under green-manure crops. *Sesbania* makes a fast growth and should be a very beneficial cover crop. It may be possible to grow two such crops during the summer, plowing under the first crop in late June or July and the second in August. A crop of Hubam sweetclover sown in the fall could be plowed under the following spring.

Grapefruit and oranges grown on the experimental farm require about 5 acre-feet of water each year. Grapefruit grown on this soil but irrigated for several years with turbid water from the Colorado River yields from 400 to 1,000 boxes an acre, depending on the age of the trees, care given them, and fertilization practices. Average yields are about 600 boxes. About 70 orange trees grow on an acre. Yields of the Valencia variety are about 3 boxes and of the Washington Navel about 2 boxes a tree. The use of ammonium phosphate fertilizers and the plowing under of green cover crops have proved highly beneficial for citrus fruits.

It is possible that melons and certain winter vegetables may be grown successfully. Difficulties, however, have been experienced with nematodes, which have killed grapes, tomatoes, and figs.

Dates are being produced in Imperial, Coachella, and Salt River Valleys on soils very similar to those mapped in this area. The production of dates is an expensive specialized agricultural enterprise that might prove successful in this area. Good-quality dates are produced on light-textured sandy soils in sections where the temperature is high. The different varieties yield somewhat differently, but the Deglet Noor, which has been grown in the Yuma Valley, produces between 150 and 200 pounds a tree with 45 trees on an acre.

Information relating to production and yields of alfalfa, citrus fruits, cotton, sweetpotatoes, melons, and other crops grown on somewhat similar soils of the Mohave, Anthony, and Cajon series is given in the soil surveys covering the Salt River Valley area,[8] the Tucson area,[9] and the Casa Grande area, Arizona.[10]

It should be understood, however, that the soils of this area are sandier and lighter in texture and probably somewhat less fertile than the soils of the other areas named, and that they exist under a somewhat hotter and drier climate. For these reasons they probably would be somewhat less productive of most crops and would require more water for crop production. The detailed description of each soil type should be carefully studied before making final conclusions that an individual soil type—for instance, Mohave loamy sand—in the Yuma Desert area will produce yields equal to those

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[8] HARPER, W. G., YOUNGS, F. O., STRAHORN, A. T., ARMSTRONG, S. W., and SCHWALEN, H. C. SOIL SURVEY OF THE SALT RIVER VALLEY AREA, ARIZONA. U. S. Bur. Chem. and Soils ser. 1926, No. 32, 55 pp., illus. [1931.]

[9] YOUNGS, F. O., SWEET, A. T., STRAHORN, A. T., GLASSEY, T. W., and POULSON, E. N. SOIL SURVEY OF THE TUCSON AREA, ARIZONA. U. S. Bur. Chem. and Soils ser. 1931, No. 19, 60 pp., illus. [1936.]

[10] POULSON, E. N., WILDERMUTH, R., and HARPER, W. G. SOIL SURVEY OF THE CASA GRANDE AREA, ARIZONA. U. S. Bur. Plant Indus. ser. 1936, No. 7, — pp., illus. 194_.

on the same or a similar soil type in other areas. In some places, such as in the Yuma and Salt River Valleys, soils have been irrigated with muddy waters that have enriched the soil by deposition of sediment, and even the original soil materials in different areas differ somewhat in content of organic residues or other plant nutrients that may have a marked influence on yields.

Duty of water and yields on soils in the group of those moderately well suited to irrigation and crop production should be much more satisfactory than on other soils of the area.

The results of mechanical analysis and moisture equivalent determination of representative samples of soils of the Yuma Desert area, by R. H. Kellner, assistant agricultural chemist at the University of Arizona, Tucson, Ariz., are given in table 3.

TABLE 3.—*Mechanical analyses and moisture equivalents of selected soil samples from the Yuma Desert area, Arizona*

Soil type and sample No.	Location	Depth	Sand	Silt	Clay	Moisture equivalent
Mohave loamy sand:		*Inches*	*Percent*	*Percent*	*Percent*	*Percent*
511762	1½ miles east of center of sec. 36, T. 11 S., R. 21 W.	0-8	96	2	2	3.70
511763		8-30	97	2	1	3.25
511764		30-45	95	2	3	10.80
511765		45-60	92	3	5	8.26
511766		60-80	87	6	7	12.45
Anthony fine sand:						
511701	Southwest corner of sec. 13, T. 11 S., R. 21 W.	0-8	97	2	1	4.05
511702		8-30	96	2	2	5.12
511703		30-50	93	4	3	5.73
Cajon loamy sand:						
511758	½ mile west of center of sec. 15, T. 9 S., R. 21 W.	0-12	95	3	2	4.94
511759		12-30	95	3	2	4.45
511760		30-48	96	2	2	3.46
511761		48-72	97	2	1	3.33
Whitlock sand:						
511762	½ mile north of center of sec. 11, T. 11 S., R. 22 W.	0-8	96	2	2	3.70
511763		8-30	97	2	1	3.25
511764		30-45	95	2	3	10.80
511765		45-60	92	3	5	8.26
511766		60-80	87	6	7	12.45
Superstition sand, hummocky phase:						
511744	NW¼ sec. 8, T. 9 S., R. 21 W.	0-20	99	0	1	3.75
511745		20-40	98	1	1	4.38
511746		40-58	96	2	2	4.75
511747		58-76	96	2	2	4 92
511748		76-88	98	1	1	4.02

Moisture equivalent is an arbitrary figure of considerable empirical value and represents the amount of water a soil will hold under specific conditions against a force of 1,000 times gravity. It is slightly below the optimum moisture-holding capacity of the soil. The water-holding capacity represents the maximum water-holding capacity of the soil and is slightly higher than the actual water-holding capacity in the field.

It will be noted that all surface soils and most of the subsoil layers are extremely high in content of sand and low in silt and clay. The moisture equivalents in all instances are low and in most of the samples very low. The subsoil layers of Mohave loamy sand and Whitlock sand contain substantially more silt and clay and have considerably higher moisture equivalents. These determinations indicate that none of these soils has more than a moderately good mois-

ture-holding capacity. Several of them have very low moisture-holding capacity and would need frequent irrigation, and, unless unusual precautions were taken, large losses of water by deep percolation and evaporation would occur.

Results of laboratory studies made at the University of Arizona on selected samples of soil taken in virgin and irrigated areas on the University of Arizona Yuma Mesa Experimental Farm are given in table 4.

TABLE 4.—*Results of laboratory studies of selected soil samples on University of Arizona Yuma Mesa Experimental Farm*

Location	Description	Depth	Sand (1.0–0.05 mm.)	Silt (0.05–0.005 mm.)	Clay (0.005–0 mm.)	Colloid (0.002–0 mm.)	Moisture equivalent	Water-holding capacity	Total salts	Calcium carbonate	pH
		Inches	*Per-cent*	*Per-cent*	*Per-cent*	*Per-cent*	*Per-cent*	*Per-cent*	*Parts per million*	*Per-cent*	
Block 4-E 2	Virgin [1]	0–24	94.6	2.0	3.4	3.2	4.12	6.22	165	-------	----
Block 3-F 2	do.[1]	0–24	89.6	4.6	5.8	3.1	4.53	7.16	205	3.27	7.7
Block F 2	Irrigated since 1927.[2]	0– 8	85.8	3.8	10.4	9.4	7.16	11.33	450	3.48	7.9
Field A	Irrigated since 1921.[2]	0– 8	65.8	10.3	23.9	22.4	16.83	26.60	545	6.83	7.8
		8–24	90.8	4.8	4.4	3.9	5.36	8.47	330	-------	----

[1] These samples are of Superstition sand. They probably are fairly representative of the type in the Yuma-Wellton area, and the analyses correspond rather closely with those of samples of the same soil taken by the Bureau of Soils on the Yuma Mesa in 1904.

[2] These samples are of Superstition sand, silted phase, which was originally typical Superstition sand but has been modified by deposition of silt by muddy irrigation water.

The analyses of samples set forth in table 4 indicate the sandy character and low moisture-holding capacity of the virgin Superstition sand, an extensive soil on the Yuma Mesa and in the Yuma Desert area. They also show that the so-called silt deposited by irrigation consists largely of colloidal clay. This clay probably is heavier than would be desirable throughout the entire profile of a soil under irrigation. Textural conditions similar to those of the lowest layer of Mohave loamy sand and Whitlock sand shown in table 3 are fairly desirable, although they are too light and sandy to be ideal. Soils that are as sandy as Superstition sand may be expected to function very similarly to soils on the Yuma Mesa Experimental Farm, but the large quantities of dark-brown fine-textured sediments that have enriched the soil on the farm would not be present in the irrigation water that may be supplied lands in the Yuma Desert area. Several past attempts to farm Superstition sand, hummocky phase, on the Yuma Mesa have failed. The water used was from wells and, of course, carried no sediments. Distribution of water was difficult, desirable moisture conditions were hard to maintain, and the loose drifting sand buried young plants and cut off tender shoots. The mechanical analyses and moisture equivalents indicate the comparative quality of soil and its suitability for irrigation. By studying descriptions of the profiles of other soils in the area and by comparing their characteristics with those for which laboratory data are given and with those for which both laboratory data and results in the field with irrigated crops are available, the quality of the soil, the probable water requirements, and crop yields can be estimated rather closely.

DRAINAGE AND IRRIGATION

The soils and substrata in this area are so porous that poor drainage or accumulations of salts, or "alkali," at or near the surface probably would not develop under irrigation. There are no excessive accumulations of salts in the area at present, and although many of the soils are naturally high in soluble mineral salts, these probably would be carried by irrigation water deeper into the soil and below the reach of plants.

Development of an irrigation system to supply water for about 80,000 acres of Yuma Mesa lands is now well under way. The water is to be diverted through a main canal from the Colorado River at Imperial Dam and carried by gravity across the Gila Valley to a point near the Southern Pacific Railroad about one-half mile west of Fortuna, where a pumping plant will be installed to lift the water about 55 feet. Further distribution of water to the Yuma Desert area is planned by installation of a series of pump units, each of which would lift water to canals located at successive higher elevations.

The cost of the water supply for each acre of land will depend on the cost of development and delivery of water to the land and the quantity required to produce crops. This cost probably will increase with each higher lift of water. It is planned that water will be delivered by the Government in concrete-lined laterals to each 160 acres. The farmer then will be required to level his land and establish his distributary system of ditches. It is impracticable at this time to estimate the actual cost of land and water supply, because this depends somewhat on an unknown area of land to be irrigated and on the quantity of water needed to produce crops. The quantity actually delivered to the farms must be large enough not only to supply that actually absorbed by the plants but also that lost by deep percolation and evaporation. The loss by deep percolation doubtless will be high on the looser soils unless some special means of distribution is used. A sprinkling system would largely eliminate this waste but would be very costly.

MORPHOLOGY AND GENESIS OF SOILS

The Yuma Desert area is situated in the southwestern desert region and, according to records of the United States Weather Bureau stations, is in a region of the lowest rainfall and greatest percentage of sunshine in the United States. The mineral materials from which soils of the area have been formed represent alluvial-fan, river-terrace, and aeolian deposits.

The alluvial fans have been built of angular rock and sand fragments, with a small proportion of finer particles, washed from the Gila Mountains adjacent to or partly within the area surveyed. Although these mountains are highly mineralized and rocks of mixed lithological character occur in the alluvial fans, those of granite or granitic gneiss predominate. The alluvial-fan accumulations near their western limits merge with old Colorado River terrace deposits, which are high in content of well-rounded gravel and sand of highly mixed mineralogical character. Heaped on top of the old terraces in many places, and to some extent on top of alluvial-fan sediments, are wind-laid sands derived in part from local sandy and gravelly al-

luvial materials and in part from more distant stream or lake shore deposits. Climate, environment, vegetation, and other biollogical forces are primary factors that influence development of specific soil characteristics. In this area, where the vegetal cover is sparse and has but little direct influence on soil formation, parent material, moisture, temperature, and aeration have been effective forces because of their relation to oxidation, leaching, hydrolysis, translocation, and accumulation of soil-forming material. Although the colloid of the Desert soils has many of the characteristics of soils where the rainfall is from three to five times as great, nevertheless the alteration and decomposition of the parent rocks is slight.[11]

The profile characteristics of the Mohave, Whitlock, and Superstition soils represent the important morphological and evolutional or genetic developments.

The soils of the Whitlock series in some respects appear to have a more pronounced profile development in the deeper part than do the other soils.

A description of a representative profile of Whitlock loamy sand shows the following layers:

1. Dark-brown or black water-worn pebbles forming a so-called desert pavement about 1 or 1½ inches thick. The pebbles have accumulated on the surface owing to removal of finer sediments by either wind or water. They are stained and have a dark bluish-black burnished appearance on exposed surfaces, but some have a very different shade or color when freshly fractured. The characteristic dark color of exposed surfaces is caused, presumably, by accumulations of oxidized mineral compounds, probably manganese and iron, which may be affected by chemical and physical reactions both on the surface and within the rock, after rainfall during the summer season when temperatures are high. The desert pavement is not uniformly developed and does not occur everywhere.
2. 0 to 8 inches, beneath the desert pavement or in places where no pavement occurs is light reddish-brown very mildly calcareous or noncalcareous rather loose or friable sandy or gritty material. In places, but not everywhere, there is a slightly crusted vesicular surface layer ranging from about ¼ to 2 inches in thickness. This layer is thicker and occurs more generally in level or slightly depressed areas. The formation of this structure probably is due to physical phenomena relating to temperature, rainfall, and soil air after periods of rainfall during the summer when the surface of the ground is heated. This crust may or may not be calcareous.
3. 8 to 18 inches, light reddish-brown gritty firm but friable mildly calcareous material. This becomes more calcareous with depth.
4. 18 to 28 inches, material same as above but slightly firmer, very slightly heavier, and containing many irregular-shaped but somewhat rounded nodules of calcium carbonate.
5. 28 to 36 inches, rather hard or somewhat cemented gritty, sandy, or gravelly materials containing many fragments and nodules of calcium carbonate. This horizon, owing to the cemented condition, is difficult to dig with a shovel but may be easily broken with a pointed iron bar. When moistened, however, it becomes softer and may be dug with a shovel. The principal cementing constituent of this horizon appears to be calcium carbonate, but it is possible that sodium or aluminum silicates and other soluble cementing compounds are present also.
6. 36 inches+, very friable or loose highly calcareous gravelly or sandy deposits, probably very similar to the original parent material.

[11] Evidence supporting this statement is contained in an unpublished paper, by I. C. Brown and M. Drosdoff, on file in the Division of Soil Chemistry and Physics, Bureau of Plant Industry, U. S. Department of Agriculture.

This soil has developed from old Colorado River terrace deposits and alluvial-fan materials borne from the Gila Mountains, under true desert conditions of hot temperatures, a rainfall of about 3 inches, and a sparse stand of desert shrubs and cacti. In some places it appears to have lain in place a longer period than other soils of the area. The outstanding feature of this soil is the pronounced accumulation of calcium carbonate together with other mineral salts in the subsoil. These, presumably, have been accumulated in the soil by the release of calcium, magnesium, and other minerals through hydrolysis, oxidization, and the processes of carbonation. It is also possible that translocation of these products has taken place, the materials being moved downward to the depth to which water penetrates after periods of heaviest precipitation.

Soils of the Superstition series have developed from Colorado River terrace deposits, together with an admixture of alluvium from the Gila Mountains and wind-deposited sandy material that has been derived from both local and somewhat distant sandy deposits. The Superstition soils generally are higher in siliceous material than the Whitlock or Mohave soils, but they contain an appreciable quantity of the darker fragments of granite and other rocks. This is more pronounced in the bodies most distant from the mountains or at the western margin of the area. These soils, in many places, occur in slightly lower areas than the Whitlock soils and in such locations represent materials that have not been in place so long as have the materials giving rise to the Whitlock soils. In other places, where the soil occurs farther away from the mountains, it receives no run-off, whereas some of the Whitlock soils receive some moisture as run-off from the Gila Mountains.

Owing mainly to more recent deposition of parent material and to lack of moisture, these soils exhibit less development than the Whitlock and the Mohave soils. The covering of desert pavement is lacking in most places. The Superstition soils have the following general profile:

1. 0 to 8 inches, pale reddish-brown or grayish-brown loose or very sligntly firm material (Superstition loamy sand and Superstition sand), or loose incoherent fine sand or sand that constantly shifts during windstorms (Superstition sand, hummocky phase). This topmost horizon generally is very mildly calcareous.
2. 8 to 20 inches, material that differs from the overlying material in being slightly firmer. The lower part of this horizon is mildly or moderately calcareous in places.
3. 20 to 36 inches, pale reddish-brown firm or very weakly cemented friable moderately or highly calcareous slightly loamy sand containing a few small irregular-shaped nodules of calcium carbonate.
4. 36 to 45 inches, sand of similar color and texture as that above, but a higher content of small irregular-shaped lime nodules gives the soil a light grayish-brown or brownish-gray color. This horizon is weakly cemented and very highly calcareous. It is more difficult to penetrate than other horizons but can be dug when dry with a shovel and is very easily dug when moist.
5. 45 inches+, parent material or but slightly altered substratum of pale reddish-brown loose mildly or moderately calcareous sand. This horizon, as well as the entire soil, contains a few particles of gravel.

The soil-forming agencies responsible for the development of the Superstition soils are practically identical with those functioning in the Whitlock soils. The dissimilarities are due to a shorter period

since deposition of the parent material has occurred, and to the fact that it is slightly more siliceous in some places; in other places to the fact that only moisture from rains has been a factor, whereas parts of the Whitlock soils receive small quantities of moisture as run-off from the Gila Mountains, in addition to moisture from rains.

The Mohave soils are developed mainly on alluvial fans in the southeastern part of the area. Parent mineral material has been eroded and washed from the Gila Mountains and is derived from granite, granitic schist, or gneiss, and less amounts of other igneous rocks of mixed mineralogical character. A profile of Mohave loamy sand occurring in this area is described as follows:

1. 0 to 7 inches, light reddish-brown or pinkish-brown firm but friable noncalcareous slightly micaceous gritty loamy sand. The sand and gritty material are angular granitic fragments of high quartz content. This material may represent a true surface horizon or it may be a more recent overwash.
2. 7 to 9 inches, slightly reddish brown slightly more compact noncalcareous sandy loam. Apparently this layer has undergone slightly more oxidization than the surface layer.
3. 9 to 20 inches, rich reddish-brown mildly or moderately calcareous heavy sandy loam. Between depths of 9 and 11 inches are a few tiny veins of gray lime carbonate, and below them are gray highly calcareous flecks and spots.
4. 20 to 48 inches, sandy loam of comparatively high colloid content. This material has a predominant rich reddish-brown color with many gray or white spots of segregated lime and some gray irregular-shaped but somewhat rounded lime nodules. This material is so hard when dry that it is almost impossible to dig with a shovel and difficult to penetrate with an iron bar, but when moist it may be easily dug with a shovel.
5. 48 inches+, pinkish-brown comparatively loose moderately or highly calcareous slightly loamy fine gravelly and coarse sandy angular granitic material that appears to be but very slightly or totally unaltered chemically since deposition.

The alluvial fans on which the Mohave soils are developed have, for the most part, been deposited subsequent to the Colorado River terraces, but in many respects the Mohave soils display greater development of a profile than do other soils of the area. This may be due to the larger quantity of moisture received on the Mohave soils in the form of run-off from the mountains and its effects on hydrolysis and oxidization of the feldspathic minerals in the granitic materials, and probably in part to the higher silica content of the Colorado River deposits and the wind-laid sediments.

The Anthony soils are closely related to the Mohave soils in origin and mode of formation, but soil-developing forces have made much less impression on the parent alluvial materials. Hydrolysis has been a minor process, translocation of calcium carbonate to the subsoil has been less than in the Mohave soils, and but little colloidal material has accumulated or developed. The subsoil is practically the same color as the surface soil and is but slightly heavier, but it is slightly more calcareous and contains faint-gray veins where calcium carbonate has accumulated.

The Cajon soils represent more recent granitic alluvial materials that have undergone practically no soil development.

SUMMARY

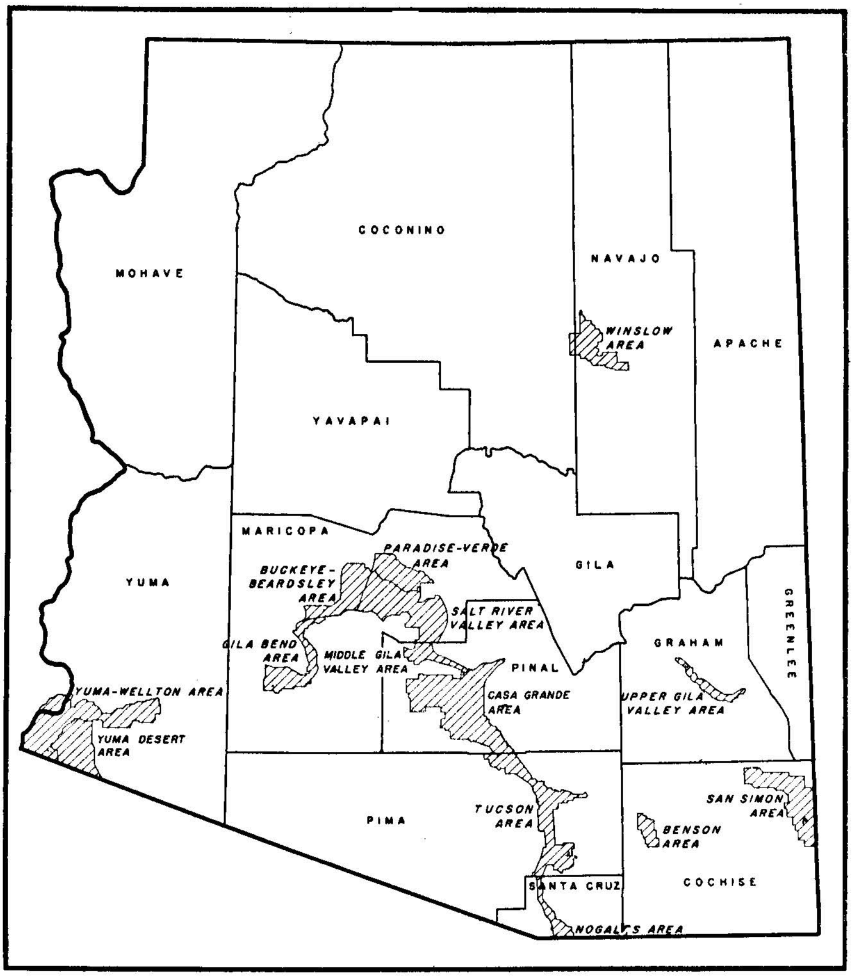
The Yuma Desert area is in the hot southwestern desert region, where rainfall is very low. The area includes about 272 square

miles between the Gila Mountains on the east, the United States-Mexico boundary on the south, United States Highway No. 80 on the north, and the eastern boundary of the Yuma-Wellton area on the west. Other than a small part of the Gila Mountains that have been included, the area is composed largely of smooth-surfaced, gently sloping, rolling, or hummocky sandy soils that have been derived from alluvial materials washed from the Gila Mountains, old Colorado River terrace deposits, and wind-laid sands.

The climate is strictly that of the desert; the vegetation is scanty and includes mainly creosotebush, galleta grass, and bur-sage, with scattered paloverde and other trees, cacti, and grasses growing mainly along washes carrying occasional run-off from the Gila Mountains. No crops are produced in the area at present (1938), but agricultural development is contingent on development of irrigation water, the initial works for which are now under construction.

The soils of this area are mapped in several series, types, and phases. For purposes of land classification they are grouped as follows: Soils moderately well suited to irrigation, soils rather poorly suited to irrigation, soils very poorly suited to irrigation, and soils unsuited to irrigation.

The agricultural possibilities and irrigation requirements are estimated largely on the basis of experience in cultivating soils at the Yuma Mesa Experimental Farm and other farms located on the mesa near Yuma. All the soils are exceptionally low in organic matter and may benefit from any practice that will supply that need. It is probable that crops may be somewhat diversified on the Mohave, Anthony, and the most desirable types of the Whitlock soils, but other soils are so sandy that only certain winter vegetables, citrus fruits, and dates are likely to succeed. The area lies in a comparatively frost-free district.



Areas surveyed in Arizona shown by shading.

U. S. GOVERNMENT PRINTING OFFICE: 1941

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SOIL MAP
YUMA DESERT AREA
ARIZONA

UNIVERSITY OF ARIZONA AGRICULTURAL EXPERIMENT STATION
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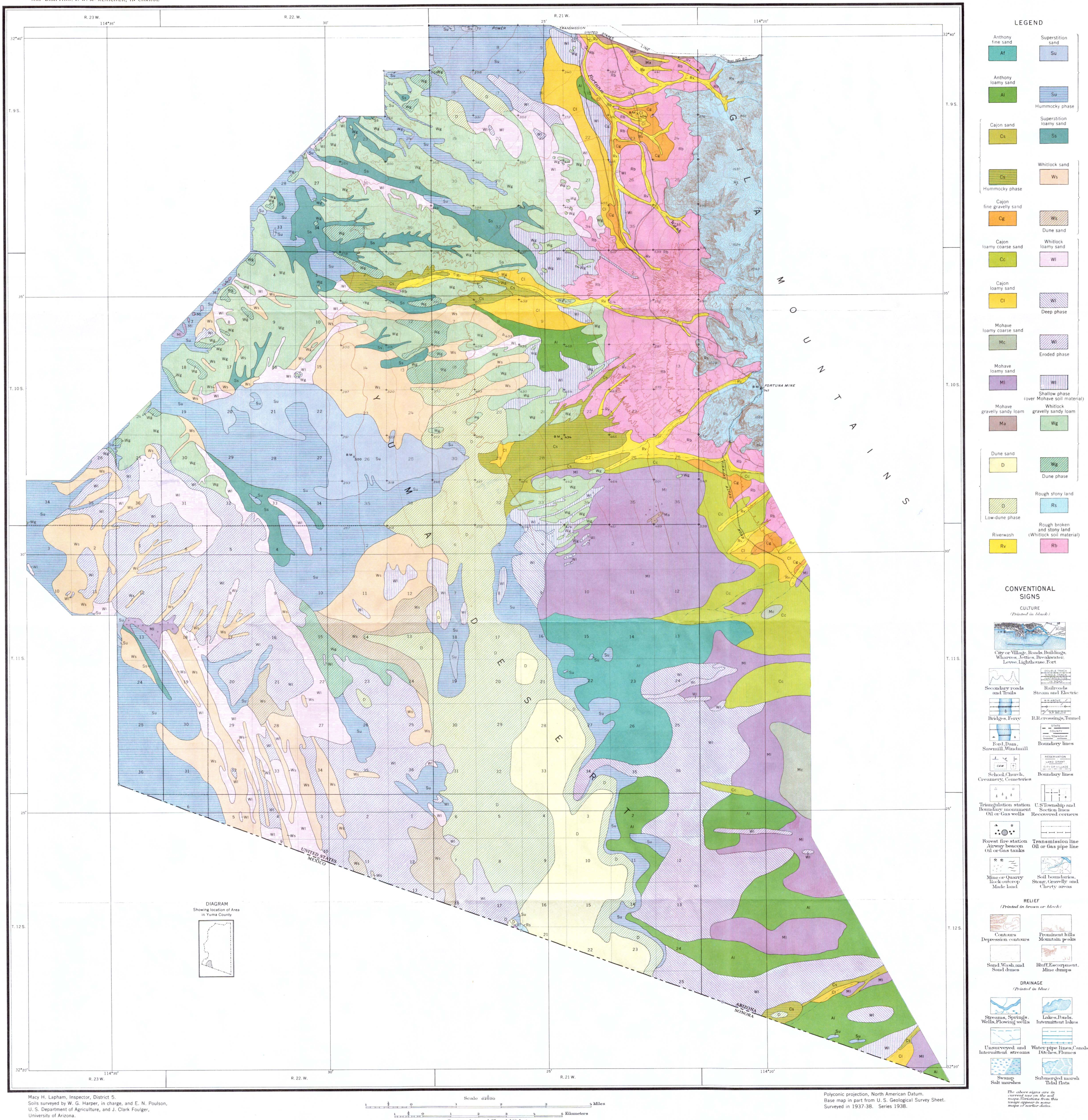

Macy H. Lapham, Inspector, District 5.
Soils surveyed by W. G. Harper, in charge, and E. N. Poulson, U. S. Department of Agriculture, and J. Clark Foulger, University of Arizona.

Scale $\frac{1}{62500}$

Contour interval 25 and 100 feet changing on the 1000 foot contour
Datum is mean sea level

Polyconic projection, North American Datum.
Base map in part from U. S. Geological Survey Sheet.
Surveyed in 1937-38. Series 1938.